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SYSTEM, APPARATUS AND METHOD FOR CONTROLLING IGNITION INCLUDING RE-IGNITION OF GAS AND GAS FIRED APPLIANCES USING SAME

The present application claims the benefit of U.S. provisional application number 60/423,509 filed November 4, 2003, which is incorporated herein by reference in its entirety.

1. FIELD OF INVENTION

The present invention generally relates to systems and methods for controlling ignition of gas, more particularly to a systems and methods for controlling ignition including re-ignition of gas when using electrical resistance igniters, even more particularly to systems and methods for controlling ignition of gas for gas fired appliances and water heaters and more specifically to such systems and methods that utilize microprocessors/ micro-controllers for performing such control functionalities.

2. BACKGROUND OF THE INVENTION

There are a number of appliances such as cooking ranges and clothes dryers and water heaters in which a combustible material, such as a combustible hydrocarbon (e.g., propane, natural gas) is mixed with air (i.e., oxygen) and continuously combusted within the appliance or water heater so as to provide a continuous source of heat energy. This continuous source of heat energy is used for example to cook food, dry clothes and heat water to supply a source of running hot water.

Because this mixture of fuel and air (i.e., fuel/ air mixture) does not self-ignite when mixed together, an ignition source must be provided to initiate the combustion

process and to continue operating until the combustion process is self-sustaining. In the not too distant past, the ignition source was what was commonly referred to as a pilot light in which a very small quantity of the combustible material and air was mixed and continuously combusted even while the heating apparatus or appliance was not in operation. For a number of reasons, the use of a pilot light as an ignition source was done away with and an igniter used instead.

An igniter is a device that creates the conditions required for ignition of the fuel/ air mixture on demand, including spark-type igniters such as piezoelectric igniters and hot surface-type igniters such as silicon carbide hot surface igniters. Spark-type igniters that produce an electrical spark that ignites gas, advantageously provide very rapid ignition, which is to say, ignition within a few seconds. Problems with spark-type igniters, however, include among other things the electronic and physical noise produced by the spark.

With hot surface igniters, such as the silicon carbide hot surface igniter, the heating tip or element is resistively heated by electricity to the temperature required for the ignition of the fuel/ air mixture, thus when the fuel/ air mixture flows proximal to the igniter it is ignited. This process is repeated as and when needed to meet the particular operating requirements for the heating apparatus/ appliance. Hot-surface-type igniters are advantageous in that they produce negligible noise in comparison to spark-type igniters. Hot surface-type igniters, however, can require significant ignition/warm-up time to resistively heat the resistance igniter sufficiently to a temperature that will ignite the gas.

There are several manufacturers of hot surface igniters used and an igniter from any one manufacturer, because of its particular material composition, mass, and physical configuration, will generally heat up at a different rate to a different final temperature than an igniter from another manufacturer. For example, when energized at 115 volts, igniters from one manufacturer may heat up to a temperature sufficient to ignite gas, approximately 1600 °F., in approximately 5 seconds, and to a relatively stable final

temperature of approximately 2500 °F when energized for 20 seconds or longer. An igniter from another manufacturer may require more or less time to heat up to 1600 °F and may attain a lower or higher final temperature. The rate of temperature change and the final temperature attained also depends on the value of the applied voltage. Specifically, when the nominal applied voltage is lower, the igniter heats up slower and attains a lower final temperature than when energized at higher voltage; when the applied nominal voltage is relatively greater, the igniter heats up faster and attains a higher final temperature.

Hot surface ignition systems include a control module that, among other functions, establishes the length of the igniter warm-up time period. When it is known that a particular igniter having a fast warm-up time will be used, the length of the igniter warm-up time period can be established at a relatively low value, for example, at 15 seconds. However, when the particular igniter to be used has a slow warm-up time or it is desirable that the system is to be usable with either fast or slow warm-up time igniters, the length of the igniter warm-up time period is established at a relatively large value, for example, at 45 seconds.

With regard to system operation, the 15-45-second igniter warm-up time period usually presents no particular problem because it represents the period between a call for heat and the time needed to enable the igniter to attain gas ignition temperature. From the standpoint of cooking, drying clothes and heating water such delays are expected and generally not noticeable to the user. For example, the delay in ignition of an oven is significantly less than the time to pre-heat the oven for baking or to reach broiling conditions. Thus, to the typical user the 15-45 second delay for gas ignition does not noticeably increase the preheating time or the time to reach broiling conditions. Such igniter warm-up time periods are, however, a disadvantage from the standpoint of re-ignition of the gas during a combustion/ heating process, which gas re-ignition times by established industry standards are on the order of 4 seconds or less.

One conventional oven gas burner control system that includes re-ignition capability uses a bi-metallic valve control system, where the valve remains open, so the gas can flow through for combustion, as long as the bi-metallic element is subject to heat energy above a predetermined amount. In order to keep the valve open in these types of systems the igniter must remain on (i.e., remain heated at or above the ignition temperature) throughout the entire period of burner operation so as to provide the required heat energy to the bi-metallic valve. In addition for ovens with self-cleaning capability, the igniter remains heated at or above the gas ignition temperature, during that portion of the cleaning cycle where the oven is heated to elevated temperatures to remove and/ or convert (e.g., to ash) residue (e.g., spills, drippings, etc.) on the interior surfaces of the oven. This maintenance of the igniter at or above the gas ignition temperature during the entire cooking/ heating or cleaning cycle necessarily reduces the effective service life of the igniter.

There is found in USP 4,615,282 a control module in a hot surface ignition system that includes a microcomputer programmed to provide a pre-selected igniter warm-up time period for enabling an igniter to heat up to a gas ignition temperature during normal system operation (e.g., 15 or 45 seconds) and is further programmed to provide, for test purposes only, an accelerated igniter warm-up time period (e.g., 10 seconds) that is shorter than the pre-selected igniter warm-up time period but sufficiently long for enabling the igniter to heat up to a temperature sufficiently high to ignite gas. The program for providing the accelerated igniter warm-up time period is automatically executed responsive to a unique signal from a detachably connected test device to the control module. It is further provided that this signal is unique and cannot be generated by the system itself under normal or abnormal conditions.

It thus would be desirable to provide a new system, apparatus and/or device to control the operation of the igniter so the igniter is capable of re-igniting the gas within desired time periods without having to maintain the igniter in a continuous "on" state and methods for controlling igniter energization/ operation. It also would be desirable to

provide such a control system and method where the igniter is warmed-up to the ignition temperature for igniting the gas and thereafter the operation of the igniter is controlled so as to maintain the igniter in a state for rapid re-ignition of the gas. It would be particularly desirable to provide such a device and method that would control igniter energization so as to extend the operational life of the igniter in comparison to the operational life for igniters being controlled by prior art control devices. Such gas control systems, apparatuses and devices preferably would be simple in construction as compared to prior art systems, apparatuses or control devices and such methods would not require highly skilled users to utilize the device.

SUMMARY OF THE INVENTION

The present invention features a gas control device being configured and arranged so as to control operation of a hot surface igniter so that such igniter is warmed-up to temperatures at or above the ignition temperature of a gas when a call for heat is made. Such a gas control device also is configured and arranged so that following such ignition operation, the igniter is controlled so the igniter is capable of rapidly re-igniting the gas (i.e., re-igniting the gas within desired re-ignition time period) without having to continuously maintain the igniter at or above the gas ignition temperature as is done with conventional gas control circuitry. More particularly, the gas control device includes circuitry that controls energization of the igniter for ignition of the gas and, after ignition of the gas is determined to have occurred, controls energization of the igniter so that the igniter can be warmed up to ignition temperature conditions within desired re-ignition time periods. Also featured are systems and apparatuses embodying such control devices as well as methods related thereto.

There also is featured a gas control system that controls energizing an electric resistance igniter from a power source and includes a control device being configured and arranged so as to control operation of the electric resistance igniter. More particularly, the control device is configured and arranged to warm-up the electric resistance igniter to

temperature at or above an ignition temperature for a gas being combusted. Further, the control device is configured and arranged so that following successful ignition of the gas, operation of the electric resistance igniter is controlled so the electric resistance igniter is at a temperature less than the gas ignition temperature and so the electric resistance igniter can be re-heated so as to re-ignite the gas within a desired re-ignition time period.

In more specific embodiments, the gas control system further controls operation of one or more gas control valves, which valves control the flow of gas for combustion. In addition, the control device is configured and arranged so as to open the one or more gas valves after the control device determines that the electric resistance igniter is heated to a temperature at least equal to the gas ignition temperature.

Other aspects and embodiments of the invention are discussed below.

DEFINITIONS

The instant invention is most clearly understood with reference to the following definitions:

The term gas shall be understood to mean any gaseous combustible material as is known to those skilled in the art used in connection with gas-fired appliances, such as those used for cooking of food and drying of clothes (e.g., stoves, ovens, clothes dryers) and water heaters and further includes, but is not limited to propane, natural gas, city gas, and manufactured gas.

BRIEF DESCRIPTION OF THE DRAWING

For a fuller understanding of the nature and desired objects of the present invention, reference is made to the following detailed description taken in conjunction with the accompanying drawing figures wherein like reference character denote corresponding parts throughout the several views and wherein:

FIG. 1 is a schematic block diagram of a gas-fired appliance including a gas control system according to the present invention illustrating control of a gas burner;

FIG. 2 is a schematic block diagram of a gas-fired appliance including a gas control system according to the present invention illustrating control of a plurality of gas burners;

FIGS. 3A-D illustrate a flow diagram of a control methodology according to the present invention;

FIG. 4 is a schematic block diagram of a gas-fired appliance including an exemplary igniter control circuitry for a gas control system according to an embodiment of the present invention; and

FIG. 5 is a flow diagram illustrating the energizing process for an igniter being controlled by the igniter control circuitry of FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

As discussed above, we now provide an ignition system that comprises a control device that can control operation of an electric resistance igniter, such as a sintered electrical igniter. Exemplary preferred igniters to use in an ignition system of the invention include sintered ceramic igniters such as those igniters disclosed e.g. U.S. Patent 6,852,629; 6,474,492; and 5,801361, among others.

The control device is suitably configured to (i) heat the igniter to temperature at or above an ignition temperature for a gas being combusted, and (ii) following successful ignition of the gas, to control operation of the igniter so the igniter is at a temperature less than the gas ignition temperature and so the electric resistance igniter can be re-heated so as to re-ignite the gas within a desired re-ignition time period. Preferably, the temperature of the igniter is maintained at desired levels (e.g. at ignition temperature or below ignition temperature) by monitoring amperage. Preferably, the system suitably may only switch on gas flow when a predetermined current level is attained to the igniter.

Suitably, the control device can operate so that the electrical resistance igniter is maintained at a temperature of about 100°C or more, such as 200°C, 300°C, 400°C, 500°C, 600°C or 1000°C or more less than a targeted gas ignition temperature (e.g. a targeted gas ignition temperature may be about 1100°C, 1200°C, 1300°C or 1400°C, such as 1100°C to 1400°C). The electrical resistance igniter also suitably may be maintained at a non-elevated temperature (i.e. maintained at ambient temperature) during non-ignition periods. For many applications, however, it will be preferred that the igniter is maintained at some temperature above room or ambient temperature, but below ignition temperature (e.g. below about 1200°C, 1150°C or 1100°C) during periods where ignition is not needed or desired.

Preferably, an ignition system of the invention provides rapid ignition to gaseous fuel, e.g. where ignition occurs within about 6 seconds or less after activation of the system for ignition (i.e. re-ignition time period), more preferably within about 5, 4, 3 or even 2 seconds after activation of the system for ignition.

Referring now to the various figures of the drawing wherein like reference characters refer to like parts, there is shown in FIG. 1 a schematic block diagram of a gas-fired water heater or gas-fired appliance 10 such as a gas range or oven including a gas control system 100 according to the present invention. The gas-fired appliance 10 also includes, a control mechanism 12, a master or main gas valve 32, a burner or gas control valve 34, gas supply tubing 36, a burner 38, a flamer sensing mechanism 50 and an igniter 60. The electrical power for operating components of the gas-fired appliance is from a power supply 20 and the gas being combusted within the gas-fired appliance is from a gas source 30. In exemplary illustrative embodiments the gas source 30 is a gas supply line within a household, which gas line typically includes a manual shut-off valve and is interconnected to a gas supply line(s) of a gas utility. Also, the electrical power source 20 is the main electrical panel within a household that is electrically coupled via a breaker to the electrical lines of an electric utility.

It should be recognized that the electrical voltage or line voltage being supplied is dependent upon the location in the world as well as the operational range or variation permitted. In the United States where the specified line voltage is 220 VAC, the nominal line voltage typically ranges between about 208 VAC and about 240 VAC. In Europe and other parts of the world where the specified line voltage is 230 VAC, the nominal line voltage typically ranges between about 220 VAC and about 240VAC. Thus, line voltage variance universally can range anywhere between about 176 VAC and about 264 VAC. In the United States, there are cases where other nominal line voltages are found; in one case the nominal line voltage is 120VAC, which ranges between about 102 VAC and about 132 VAC and in another case the nominal line voltage is 24VAC, which ranges between about 20 VAC and about 26 VAC.

The control mechanism 12 is any of a number of mechanisms or switches known in the art that can provide output signals to the micro-controller 110, responsive to user inputs/ actions, so as to selectively turn the gas burner 38 on and off as well as selectively adjusting the heat-output of the gas burner. In an exemplary illustrative embodiment, the control mechanism 12 is a rotating switch as is known to those skilled in the art that is selectively rotated by a user to thereby provide the necessary signal outputs. In an alternative embodiment, the control mechanism 12 is one or more pressure sensitive switches used to turn the gas burner 38 on and off and for selecting a power level (e.g., a temperature). The pressure sensitive switch can be used in combination with an LCD or other type of visual display that displays the on-off condition and power level information to the user.

In the illustrated embodiment, there is shown a redundant gas valve sub-system comprised of a main valve 32 and a gas control valve 34, however, this shall not be construed as being limiting the present invention to the illustrative embodiment. The gas control device 100 of the present invention is contemplated for, and adaptable for, use with gas-fired appliances having a single gas control valve between the gas source 30 and the gas burner 38. The gas supply tubing 36 is any of a number of tubing products known

to those skilled in the art that are appropriate for use with gas and appropriate for interconnecting the main valve 32, the gas control valve 34 of the gas-fired appliance to the gas source 30 and in turn to the gas burner 38.

The main valve 32 is any of a number of valves known to those skilled in the art, such as a solenoid valve, that are selectively operable responsive to a control signal from the micro-controller 110. In an illustrated embodiment, the main valve 32 is suitably configured to be an on/off valve and to be in one of an open or closed position responsive to the signal(s) received from a control device such as the micro-controller 110. Similarly, the gas control valve 34 is any one of a number of control valves known to those skilled in the art that can be selectively adjusted into any of a number of positions between, and including, the closed and full-open position responsive to control signals from a control device such as the micro-controller 110. In this way, the gas control valve 34 adjusts the amount of gas flowing through the gas control valve to the burner and consequently selectively controlling the amount of heat energy being produced by the gas burner 38. The gas burner 38 is any of a number of burners as is known in the art or structures developed using well-known principles and/ or techniques by which a combustible gas is controllable intermixed with the surrounding atmosphere so as to establish a combustion process.

The flame sensing mechanism 50 is typically provided for use in determining the presence of continuous combustion of the fuel/air mixture. In one embodiment, the sensing mechanism embodies the flame electrical phenomena of flame rectification between the igniter 60 and an isolated metal sheath surrounding the igniter as the mechanism for detecting the presence of a flame. In this embodiment, a flame is detected or determined to be present if a current leakage between the igniter and the sheath is in excess of a predetermined value. In other embodiments, the flame sensing mechanism is a thermopile type of sensor that senses the temperature of the area in which the fuel/ air mixture is being combusted or comprises an optical sensor. The flame sense mechanism also may comprise the igniter shield and/or the grounded burner element. The sensing

mechanism 50 is operably coupled or interconnected to the micro-controller 110 to provide indications or signals representative of one of the presence of a flame or the lack of a flame. The actions taken by the micro-controller 110 response to such indications is hereinafter described.

The igniter 60 is any of a number of electric resistance or hot surface igniters known to those skilled in the art appropriate for the intended use/ application described herein. In a particularly illustrative embodiment, the igniter 60 is a ceramic/intermetallic hot surface igniter such as Norton Mini Igniters® manufactured by St. Gobain Industrial Ceramics Norton Igniter Products. Such an ignition device typically includes a heating element that extends outwardly from an end of the base which it is secured to. This shall be not limiting as the present invention can be used with other types of hot surface igniters as well as other types of ignition devices or igniters, such as for example Norton CRYSTAR Igniters®. In specific exemplary embodiments, the electric surface igniter 60 is an electrical resistance igniter having a nominal operating voltage of 18, 60, 70, 80, or 150 volt (V)AC, however, it should be recognized that the present invention is not particularly limited to these exemplary nominal operating voltages.

The gas control system 100 includes a micro-controller 110, a power switching mechanism 120 and a mechanism for monitoring the igniter 60 so as to determine when the igniter has reached a temperature suitable for ignition of the gas. In an illustrative embodiment, the monitoring mechanism is a current sensing mechanism 130 as is known in the art that senses the igniter current. As is known to those skilled in the art, a relationship can be established relating the igniter current to the temperature of the igniter 60. In this way, when the igniter current being sensed by the current sensing mechanism 130 reaches a predetermined value, hereinafter referred to as the current threshold, it is known that the igniter 60 has achieved the minimum operating temperature necessary to ignite the gas-air mixture. When the sensed igniter current reaches the current threshold, this condition is sometimes referred to as the ignition source being "proved". It should be recognized that other mechanisms known to those skilled in the art are contemplated for

use in the present invention for determining the operational condition of the igniter 60. For example, a temperature sensitive element (e.g., a bi-metallic element) can be positioned proximal the igniter 60 so as to provide a signal indicative of when a temperature is in excess of pre-determined value.

The power switching mechanism 120 is any of a number of circuits and/ or circuit element(s) that, responsive to control signals from the micro-controller 110, at least selectively energizes the igniter 60 (i.e., turn the igniter on) so as to heat-up or warm-up the igniter so the igniter is hot enough to ignite the gas and to de-energize (i.e., turn the igniter off) to stop the resistance heating of the igniter. As described hereinafter, in one embodiment of the present invention, the power switching mechanism 120 also is controlled by the micro-controller 110, after successfully igniting the gas, so as to maintain the igniter 60 at a predetermined temperature or in a predetermined temperature range, less than the gas ignition temperature. The system may further comprise enhanced ignition element(s) as disclosed in co-pending and commonly assigned U.S. Published Patent Application 2003-0164368A1, which is discussed further below and with particular reference to FIG. 4.

In an illustrative embodiment, the power switching mechanism 120 includes a thyristor, a rectifier which blocks current in both the forward and reverse directions. In a more specific embodiment, the thyristor is a triac as is known to those skilled in the art that blocks current in either direction until it receives a gate pulse from the microcontroller 110. Upon receiving the gate pulse, current flows through the triac. The thyristor or triac is electrically coupled to the electrical power source 20 and the hot surface igniter 60 so as to control the flow of current from the power source through the hot surface igniter. Thus, in the case where the thyristor or triac is blocking current flow, the hot surface igniter 60 is de-energized. In the case where the thyristor or triac has received a gate pulse, current flows through the hot surface igniter 60 thereby energizing the igniter and causing it to be heated.

The microcontroller 110 includes a processing unit 112, a random access memory 114, a nonvolatile memory 116 and an applications program for execution in the processing unit. The applications program includes instructions and criteria for receiving and processing the various signals being inputted to the microcontroller 110 from the igniter current sensing mechanism 130, the flame sensing mechanism 50, and the gas-fired appliance control mechanism 12. The applications program also includes instructions and criteria so as to provide output control signals to the main gas valve 32, the gas control valve 34 and the power switching mechanism 120, thereby controlling the admission of gas to the combustion area, energizing the hot surface igniter 60 and maintaining the igniter in a standby condition to re-ignite the gas within a predetermined time period. The applications program, including the instructions and criteria thereof, is discussed below in connection with FIGS. 3A-D.

The processing unit 112 is any of a number of microprocessors known to those skilled in the art for performing functions described herein and operating in the intended environment. In an exemplary embodiment, the processing unit 112 is Samsung S3C9444 or Microchip 12C671. The random access memory (RAM) 114 and the nonvolatile memory 116 is any of a number of such memory devices, memory chips, or the like as is known to those skilled in the art. The nonvolatile memory 116 more particularly can comprise either flash or spindle type of memory. In more particular illustrative embodiments, the nonvolatile memory 116 includes nonvolatile random access memory (NVRAM), read-only memory (ROM) such as EPROM. In a particular embodiment, the processing unit 112, RAM 114 and nonvolatile memory 116 are disposed/arranged so as to be co-located on a single integrated chip. This is not particularly limiting as these components can be configured and arranged in any of a number of ways known to those skilled in the art.

The operation of the gas control system 100 of the present invention, as well as an exemplary illustrative gas-fired appliance 10 embodying such a system is best understood from the following discussion and with reference to FIGS. 3A-D. Reference also should

be made to Fig. 1 and the foregoing discussion for features and functionalities of the gas control system 100 not otherwise provided or discussed hereinafter. As noted above, the following also describes the functions as well as the instructions and criteria of the applications program being executed in the processor 112 of the micro-controller 110.

The gas control system 100 is operated so the hot surface igniter 60 is de-energized and the main gas and gas control valves 32,34 are closed during those times when heat energy is not to be produced by the gas-fired appliance device 10 such as a heating unit e.g. a water heater. As such, during such non-heat producing times the gas control system 100 is in an idle state. When heat energy is to be produced by the gas-fired appliance 10, an input signal is provided to the micro-controller 110 such as a signal from the control mechanism 12. Such a signal corresponds to a signal to start the process of energizing the surface igniter 60 so as to ignite the gas/ gas burner 38, step 402. In the case where the gas control system 100 is powered down when in the idle state, such as for example after a period of time has elapsed without receiving signals to energize the igniter 60 and to ignite the gas/ gas burner 38, such a signal can be manifested by restoring power to the control system. Such signals also essentially are a call for the production of heat energy.

After receiving signals calling for heat energy to be produced, the micro-controller 110 performs a pre-start verification to detect the presence of a flame, steps 404, 406. More particularly, the micro-controller 110 evaluates the outputs, if any, from the flame sensing mechanism 50 to determine if the output signals indicate the presence of a flame. If it is determined that a flame is present (YES, Step 406) where none should be present, that indicated a fault and the micro-controller 110 outputs a lock-out signal so as to cause the gas-fired appliance 10 to be placed in a lock-out mode, Step 408. In the lock-out mode, the igniter 60 and the gas valves 32, 34 of the gas-fired appliance 10 cannot be operated (e.g., igniter cannot be energized and valves cannot be opened). Typically, the manufacturer of the gas-fired appliance provides a mechanism by which the lock-out

mode can be reset, for example after a pre-specified period of time has elapsed or after electrical power to the appliance has been removed and thereafter restored.

If it is determined that a flame is not present (NO, Step 406), the micro-controller 110 outputs a control signal to energize the igniter 60 to heat the igniter up to gas ignition temperature conditions, Step 410. More particularly, the micro-controller 110 outputs a control signal(s) to the power switching mechanism 120 to supply electrical power (i.e., voltage and current) to the igniter 60 to energize the igniter. In an illustrative exemplary embodiment, the switching mechanism 120 is selectively operated by the micro-controller 110 so the igniter 60 is heated up to gas ignition temperatures.

Using outputs from the igniter monitoring mechanism the micro-controller 110 monitors the igniter, for example the igniter temperature or parameters (e.g., igniter current) that can be related to igniter temperature, Step 412, and evaluates these conditions to determine if the igniter temperature is at or above the gas ignition temperature, Step 414. As indicated above, the igniter current can be related to the temperature of the igniter. Thus, in an exemplary embodiment, the micro-controller 110 monitors the igniter current sensing mechanism 130 to determine if the sensed or measured igniter current exceeds a current threshold. Thus, if the sensed or measured igniter current is at or above the current threshold, then the igniter temperature correspondingly is at or above the gas ignition temperature.

If it is determined that the igniter temperature is below the gas ignition temperature (NO, Step 414), a determination is made as to whether a first time-out clock has expired, Step 416. In other words, a determination is made whether the time that has elapsed since the signal to energize the igniter 60 was generated is equal to or greater than a pre-specified time period. As indicated herein, a given igniter is typically characterized by a specific time period required to warm-up the igniter so it reaches the minimum temperature required for ignition of the gas. Thus, the pre-specified time period for the first time out clock is established based on the warm-up time period of the igniter being

used. In an illustrative embodiment, the pre-specified time period is 15 seconds. If it is determined that the first time out clock has expired (YES, step 416) then the micro-controller 110 outputs a lock-out signal thereby causing the gas-fired appliance 10 to be placed in a lock-out mode, Step 408. If it is determined that the first time out clock has not expired (NO, Step 416), then the process repeats the process set forth in steps 412 and 414.

If it is determined that the igniter temperature is at or above the igniter temperature (NO, Step 414), the micro-controller outputs one or more control signals causing the main gas valve 32 and the gas control valve 34 to open thereby allowing gas to flow to the gas burner 38, Step 420. In the exemplary embodiment, the micro-controller 110 evaluates the sensed or measured igniter current and if it is determined that the sensed or measured current is at or above the current threshold, the igniter 60 is determined to be at a temperature at or above the gas ignition temperature.

After opening of the gas valves 32, 34, a time period typically is established by which the gas coming from the gas burner 38 should have ignited and a continuous sustained combustion of the gas should be established. Typically, a time period of about four (4) seconds is set for the foregoing to be accomplished. Thus, following opening of the valves 32, 34 a determination is made if a second time out clock, relating to the foregoing time period, has expired, Step 422. If the time period has not elapsed (NO, Step 422), the valves 32,34 are kept open and gas continues to flow to the gas burner 38.

If it is determined that the second time out clock has expired (YES, Step 422), the micro-controller 110, using signals from the flame sensing mechanism 50, determines if flame(s) are present indicative of the successful ignition of the gas and the establishment of a continuous sustained combustion of the gas, Step 424. If a flame is detected (YES, Step 424), the micro-controller 110 continues to keep the valves open (e.g., continues to energize the valves so as to keep them open), Step 430 and initiates or establishes the re-ignition functionality of the present invention as hereinafter described.

As the valves are kept open, signals also are generated to control or regulate the heat output of the gas burner 38. More particularly, the control mechanism 12 or a temperature-regulating device of the gas-fired appliance further provides signals (e.g., a line voltage signal) to control or regulate the heat output of the gas burner 38. In an exemplary embodiment, the temperature-regulating device or the control mechanism 12 outputs a line voltage signal to the gas control valve 34 that in turn regulates the amount of gas passing through the valve and thus the amount of heat energy being produced by the gas burner.

The process also continues to evaluate the operational status of the gas-fired appliance 10 to determine if the end of the particular heating cycle is completed or ended, Step 432. The heating process continues (NO, Step 432) until it is determined that the heating cycle is ended (YES, Step 432). When the particular heating cycle is completed or ended, the valves 32, 34 are closed, the igniter 60 is de-energized and the re-ignition functionality is terminated, Step 434.

As indicated above, if a flame is detected (YES, Step 424), the micro-controller 110 initiates or establishes the re-ignition functionality of the present invention as hereinafter described. More particularly, the micro-controller 110 outputs a control signal(s) to the power switching mechanism 120 to continue to energize the igniter 60 but so as to maintain the igniter at a standby or re-ignition standby, Step 440 and continues to monitor for the presence of a flame, Step 450. As to the energization of the igniter 60, the micro-controller 110 controls the power switching mechanism so that voltage and current being applied to the igniter are such that the igniter is being maintained at a temperature or in a temperature range that is lower than the gas ignition temperature but high enough such that the igniter can be warmed up to the minimum temperature for ignition of the gas in less than predetermined time period. In exemplary embodiments, the predetermined time period is 4 seconds or less, more particularly about 2 seconds and

more specifically within the range of from, and including, about 2 seconds to about 4 seconds.

From the monitoring of the presence of the flame, Step 450, a determination is made as to whether the flame is present or not, Step 452. If it is determined that the flames is present (YES, Step 456) the process continues to perform Steps 450 and 452 until the heating cycle is ended or a loss of flame is detected. In an exemplary embodiment, the micro-controller 110 detects the loss of flame within a second or less, more particularly within about 0.8 seconds. If it is determined that there is no flame present (NO, Step 452), then the micro-controller 110 outputs a control signal(s) to the power switching mechanism 120 so as to cause the igniter 60 to be re-heated to gas ignition temperature conditions, Step 454. Since the igniter 60 is maintained at a standby temperature (Step 440), the time to warm-up the igniter and re-establish gas ignition temperature conditions is within about 2 to 4 seconds as indicated above.

After a control signal is sent to energize the igniter and to re-establish gas ignition temperature conditions (Step 454), it is determined if a predetermined time period has elapsed since such a control signal was generated, Step 456. If the predetermined time period has not elapsed (NO, Step 456), the process continues to perform Steps 454 and 456. If the predetermined time period has elapsed (YES, Step 456), the process returns to Step 424 (FIG. 3B) for an evaluation to determine if a flame is again detected.

If a flame is not detected (NO, Step 424) either when the gas valves where initially opened after initially energizing the igniter or after an attempt was made to re-ignite the gas following the detection of a loss of flame, the micro-controller 110 outputs a control signal(s) to the power switching mechanism 120 to de-energize the igniter 60 and outputs control signals to close the main and gas control valves 32, 34, Step 460. In addition, a counter representing the number of trial-for-ignition cycles is incremented by one and the number in the counter is compared with a maximum number of trial-for-ignition cycles, STEP 462. If it is determined that the counter equals the maximum

number of trial-for-ignition cycles (YES, Step 462), then the micro-controller 110 outputs the lock-out signal, Step 408.

If it is determined that the number in the counter is less than the maximum number of trial-for-ignition cycles (NO, Step 464), then the system is purged to dissipate unburned gas or residual products of combustion, Step 464. A predetermined period of time is set for such purging that is sufficient time for the dissipation of unburned gas or residual products of combustion. The process continues with such purging (NO, Step 466) until it is determined that the predetermined trial-for-ignition time period has elapsed (YES, Step 466). After the predetermined time period has elapsed, the process returns to Step 404 (FIG. 3A) to perform the pre-start verification process.

Referring now to FIG. 2, there is shown a schematic block diagram of a gas-fired appliance having a plurality or more gas burners 38a,b including a gas control system 100' according to the present invention that configured to separately control each gas control burner. In FIG. 2, alpha characters were added to the numerical reference numerals used in FIG. 1 to identify the components corresponding to those in FIG.1 but provided for controlling one of the gas burners illustrated in FIG. 2. Thus, reference shall be made to the foregoing discussion of FIG. 1 and FIGS. 3A-D for details of the corresponding elements/ components and functionality.

As to the micro-controller 110' of this embodiment, the micro-controller including the applications program being executed in the processor 112 of the micro-controller may be e.g. suitably configured so that the micro-controller can separately control the operation of each gas burner irrespective of the operation of the other gas burner, or alternatively e.g. the microcontroller may be configured to control a single burner at a time. For example, one gas burner could be operating normally while the other of the gas burners is going through re-ignition of the gas. However, in the case of implementation of the lock-out mode (Step 408), all of the gas burners can be affected due to closure of the main gas valve. As to other aspects of the micro-controller 110 the constituents

thereof and the applications program for execution therein, reference shall be made to the foregoing discussion regarding FIGS. 1 and 4A-D.

It should be recognized that although FIG. 2 is illustrative of burners of a gas-fired range, the circuitry and system configuration illustrated in FIG. 2 is easily adaptable for use in controlling a wide range of gas-fired appliances having a plurality of more of gas burners as well as the gas burners used in ovens for baking and broiling. For example, in an exemplary illustrative gas-fired oven according to the present invention, such an oven would include a main gas valve in series with each of a bake gas valve for controlling baking and a broil gas control valve for controlling broiling. This is similar to the arrangement of the first and second gas control valves 34 a,b and the main gas control valve 32 as shown in FIG. 2. However and in contrast to the operation of a gas-fired range, in the case of an oven the bake gas control valve and the broil gas control valve although separately controllable are not energized nor opened at the same time because an oven typically is used to bake or broil and not to do both at the same time. As to other aspects, reference shall be made to the foregoing discussion for FIGS, 1-3 for further details of the use of the gas control system of the present invention for a gas-fired oven as well as other gas-fired applications not otherwise specifically enumerated herein.

Now referring to FIG. 4, there is shown a schematic block diagram of a gas-fired appliance including a gas control system according to an embodiment of the present invention. Reference shall be made to USSN 10/090,450, filed March 4, 2002 (U.S. Published Patent Application 2003-0164368A1 to Chodacki et al. published September 4, 2003), the teachings of which are incorporated herein by reference in their entirety including for details not otherwise shown in the drawing figures referred to hereinafter or that described hereinafter. Reference also should be made to the foregoing discussion for FIGS. 1 and 3A-D for details of common structure/ features/ components and method steps not otherwise described hereinafter.

The gas control system 300 further includes a zero crossing circuit 302 and a line voltage measuring circuit 304 and the applications program for execution in the processor 112 of the micro-controller 110 further includes instructions and criteria for controlling the energization of the igniter in accordance with this embodiment of the present invention.

The zero cross circuitry 302 is electrically coupled to the power source 20 to monitor the line voltage from the power source and is operably coupled to the microcontroller 110. The zero cross circuitry 302 is any of a number circuits known to those skilled in the art that is configured and arranged so as to be capable of detecting or determining when the AC line voltage crosses the time axis, in other words passes through zero voltage. The zero cross circuitry 302 also is configured and arranged so as to provide an output signal to the microcontroller 110 when the AC line voltage passes through zero voltage. In an exemplary embodiment, the output signals are digital signals.

The line voltage measuring apparatus 304 is electrically coupled to the power source 20 and is operably coupled to the microcontroller 110. The line voltage measuring apparatus 304 includes any of a number of line voltage measuring circuits known to those skilled in the art that is configured and arranged to monitor and determine the line voltage from the power source 4 and to provide output signals representative of the determined line voltage. More particularly, such circuits are configured and arranged so as to be capable of quickly determining the line voltage and providing such output signals to the microcontroller 110. In a more particular embodiment, the line voltage measuring apparatus 304 comprises a conventional resistor divider filter circuit. In an exemplary embodiment, the output signals are analog signals, however, the circuitry can be configured so as to provide digital output signals.

The power switching mechanism 320 comprises a thyristor 322, that is a rectifier which blocks current in both the forward and reverse directions. In a more specific embodiment, the thyristor 322 is a triac as is known to those skilled in the art that blocks

current in either direction until it receives a gate pulse from the microcontroller 110. Upon receiving the gate pulse, current flows through the triac. The thyristor 322 or triac is electrically coupled to the power source 4 and the hot surface igniter 60 so as to control the flow of current from the power source through the hot surface igniter. Thus, in the case where the thyristor 322 or triac is blocking current flow, the hot surface igniter 60 is de-energized. In the case where the thyristor 322 or triac has received a gate pulse, current flows through the hot surface igniter 60 thereby energizing the igniter and causing it to be heated.

The operation of the gas control system 300 is best understood from the following discussion and with reference to FIGS. 3A-D and FIG. 5. Reference also should be made to FIG 4 and the foregoing discussion of FIG. 4 and FIG. 1 for features and functionalities of the control system 300 not otherwise provided or discussed hereinafter. As noted above, the following also describes the functions as well as the instructions and criteria of the applications program being executed in the processor 112 of the micro-controller 110. The following discussion, however, is principally limited to describing the particular process associated with energizing the igniter (Step 410, FIG. 3A) according to this embodiment of the present invention.

As indicated above in connection with FIG. 3A, if it is determined that a flame is not present (NO, Step 406), the micro-controller 110 outputs a control signal to energize the igniter 60 to heat the igniter up to gas ignition temperature conditions, Step 410. According to this embodiment, the microcontroller 110 outputs a signal (e.g., a gate pulse) to the triac or thyristor 322 to fire the thyristor so that current from the power source 4 flows through the hot surface igniter 60. More particularly, the microcontroller 110 controls the triac or thyristor 322 so that such current flows continuously and so "full-on" voltage is supplied to the hot surface igniter 60, step 502. This typically produces an "over voltage" condition, that is the voltage developed across the hot surface igniter 60 is more than nominal operating voltage for the igniter(s). Consequently, the hot surface

igniter 60 heats faster to a given temperature and also will produce more heat energy in the igniter.

As indicated above, the line voltage measuring apparatus 304 monitors the line voltage of the power source 20 and provides output signals representative of the line voltage to the microcontroller. After receiving such an energizing signal, the microcontroller 110 processes the output signals from the line voltage measuring apparatus 304 to determine the amplitude of the line voltage, step 510.

The microcontroller 110 evaluates the determined or measured line voltage to determine the time period during which the "full-line" voltage is to be applied or delivered to the hot surface igniter 60, step 512. This time period is hereinafter referred to as the "full-on" time period. More particularly, the processor 112 compares the determined line voltage with a look-up table to determine the "full-on" time period appropriate for the determined line voltage. In more specific embodiment, the look-up table is stored in the nonvolatile memory 116. In an exemplary embodiment, this process of determining the "full-on" time period is completed within about a second after the signal to energize the igniter is received by the microcontroller 110.

Consequently, the processor 112 adjusts the "full-on" time period each time the microcontroller 110 receives an input signal to energize the hot surface igniter 60 based on the line voltage being measured each time. In other words, the time the "full-on" voltage will be applied or delivered to the hot surface igniter 60 will vary depending upon the line voltage being measured each time the igniter is to be energized. For example, if the measured voltage is at the lower-end of a given voltage range, then the "full-on" time period would be adjusted to compensate for this by applying the "full-on" voltage for a longer period of time. Similarly, if the measured voltage is at the higher-end of a given voltage range voltage, then the "full-on" time period would be adjusted to compensate for this by applying the "full-on" voltage for relatively shorter time than that for the low-end line voltage.

After determining the "full-on" time period, the processor 112 continuously determines if this time has expired, step 504. If it is determined that the time period has not expired (NO, step 504), then the microcontroller 110, more particularly the processor 112, controls the triac or thyristor 322 so that the "full-on" voltage continues to be applied or delivered to the hot surface igniter 60, step 502. If it is determined that the time period has expired (YES, step 504), then the processor 112 controls the triac or thyristor 322 to regulate the voltage being applied to the triac or thyristor, step 506. Thereafter, the process return to Step 412 of FIG. 3A.

It should be recognized that the igniter energizing process described in connection with FIGS 4-5, also is adaptable for use in energizing the igniter when re-igniting the gas following the detection of a flame failure (Steps 450, 452, FIG. 3C). In such a case, the igniter is in one non-heated condition or heated to a stand-by temperature condition prior to applying the full-on voltage as hereinabove described. In such cases, the micro-controller 110 would similarly determine a full-on voltage time period, control the application of the full-on voltage to the igniter for the determined time period and after expiration of the determined time period thereafter regulating the voltage to the nominal operating voltage for the igniter.

Although a preferred embodiment of the invention has been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.